Compact, Passively Q-Switched 523-nm Laser

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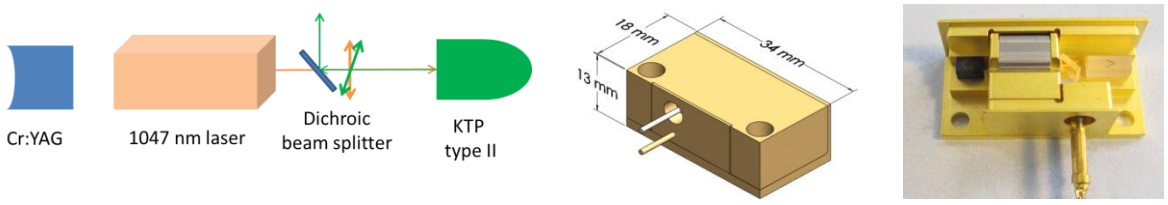
Abstract: We have developed a compact, passively Q-switched, intra-cavity frequency doubled Nd:YLF laser that produces 1-mJ of energy in a 10-ns pulse at a 1-20 Hz repetition rate.
OCIS Codes: (140.3580) Lasers, solid-state; (140.3480) Lasers, diode-pumped

1. Introduction

Compact, lightweight, and efficient lasers are essential for space based applications where there are constraints on size weight and power (SWaP). Our laser is designed to perform elemental analysis on rock samples by means of Raman and laser induced breakdown (LIB) spectroscopy. In order to obtain a high energy per pulse at repetition rates < 1 kHz, we chose Nd:YLF as the laser material as it has a longer upper state lifetime compared with the more common material, Nd:YAG. The laser is side-pumped by a semiconductor laser and passively Q-switched by a saturable absorber. A KTP crystal is placed inside the laser resonator to double the laser frequency to generate green light at 523 nm. The overall volume of the laser head is < 8 cm^3 and the weight is < 80 gm. The unique pumping geometry makes the laser power insensitive to the temperature over +/- 5 °C. The laser head is designed to be insensitive to mechanical or thermal misalignment.

2. Laser resonator

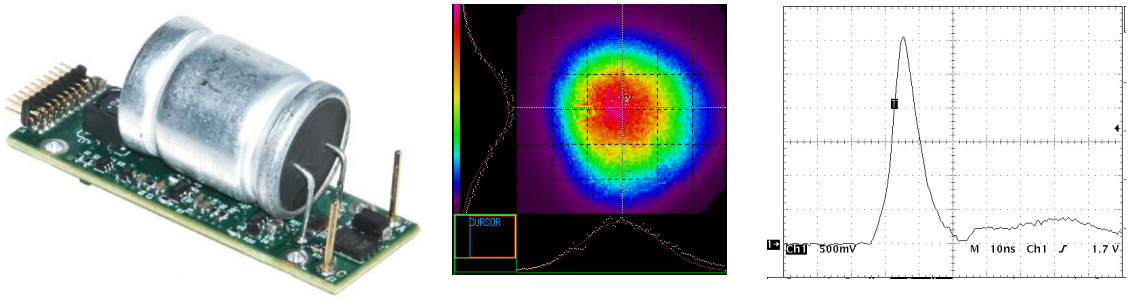
The Nd:YLF laser crystal was side pumped by a single-bar diode laser operating at 792 nm. Polarization of the pump diode laser was parallel to the c-axis of laser crystal. Absorption efficiency of Nd:YLF in this configuration is maximized [1]. Residual pump light was reflected back through the laser crystal by putting a high reflection coating at the back side of the crystal. If we assume an average absorption coefficient of 10 cm^{-1}, then the percentage of pump light absorbed in a single pass is 78% and in a double pass through the crystal is 95 %. The laser was operated at 1047 nm and was naturally linearly polarized parallel to the c-axis of the crystal. Figure 1a shows a schematic of the laser resonator. The laser was passively Q-switched by a Cr^{4+}:YAG crystal. The back surface of the Cr^{4+}:YAG was polished to a concave surface and coated with high reflector at 1047 nm and 523 nm. A type II KTP crystal is placed inside the resonator to generate green light at 523 nm. The front of the KTP crystal was polished to a convex surface and coated with a high reflector at both 1047 and 523 nm. A dichroic beam splitter that reflected 523 nm and transmitted 1047 nm was placed inside the resonator to provide the output coupling for the laser. A CAD drawing of the laser head with dimensions is shown in Figure 1b. Connection to the pump diode laser is by two electrical pins as shown in Figure 1b. A photograph of the laser head without the cover is shown in Figure 1c. An external driver, shown in Figure 2, generated the required current pulse to power the pump diode laser. Dimensions of the driver are 5 x 1.7 x 2.5 cm and the weight is 17 g. It was operated from 5 V battery. At room temperature without any active temperature control, the laser can be operated from single shot to 20 Hz, limited by the driver's ability to operate more than 20-Hz repetition rates. If a different driver is used, then the laser can be operated up to 500 Hz with a thermo-electric cooler mounted at the bottom of the laser head.



(a) (b) (c)

Fig. 1. (a) Schematic of laser resonator, (b) CAD drawing of laser head and (c) photograph of the laser without cover.

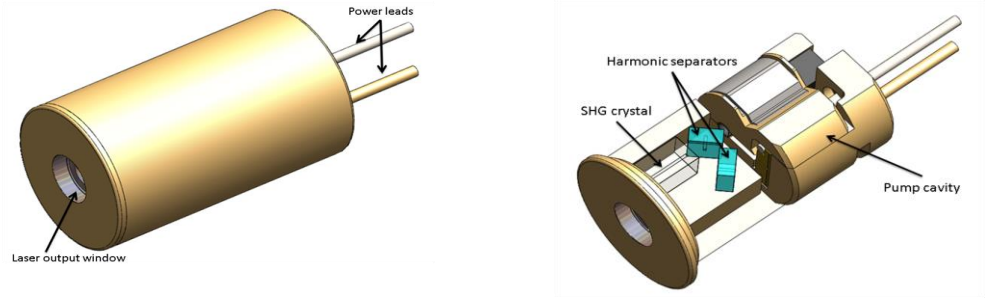
A typical laser beam profile is shown in Figure 2b and a typical temporal profile is shown in Figure 2c. The laser pulse width is ~10 ns. We measured the pulse-to-pulse timing jitter to be on the order of 1 μs which is an inherent property of passively Q-switched lasers. The energy per pulse is 1-mJ at 523 nm. The optical-to-optical efficiency is 10%.



(a) (b) (c)

Fig. 2. (a) The external laser driver, (b) a beam profile of laser, (c) and a temporal profile of the laser pulse.

We have developed a next generation laser package with smallet foot print < 4 cm^3 in volume and < 26 gm in weight without changing any of the current optics. Figure 3a shows the new design. The laser head is cylinder with 1.5 cm in diameter and 2.5 cm in length. Figure 3b shows the layout of the optics inside the housing. Smaller and lighter packages are beneficial to space appliactions as well as unmanned vehicle exploration.



(a) (b)

Fig. 3. (a) Th external laser driver, (b) a beam profile of laser, (c) and a temporal profile of the laser pulse.

3. Conclusions

We have built a compact, rugged, Q-switched, side-pumped Nd:YLF laser for space-based application. We obtained 1-mJ of energy per pulse at 523 nm. The pulse width of the laser is ~10 ns. The laser can be operated from single shot to a 20-Hz repetition rate.

4. Acknowledgements

This work was supported by a NASA Phase II SBIR (Contract # NNX12CA41C).

5. References

[1] http://www.st.northropgrumman.com/synoptics/SiteFiles/docs/PDFs/Nd_YLF_graph.pdf